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REVIEW ARTICLE

Port J Nephrol Hypert 2014; 28(4): 290-291
Advance Access publication 4 December 2014

Focus on:

Water-electrolyte balance and acid-base equilibrium – A perspective on homeostatic physiology

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Received for publication: 10/11/2014
Accepted: 20/11/2014

INTRODUCTION

In the next two issues of this Journal we propose to review the conceptual framework of water-electrolyte balance and acid-base equilibrium.

These are subjects that are not often reviewed on an integrative, whole body level, because they are considered by some as an already known matter, by others as frustratingly difficult, or even as not very relevant, by the more practically minded. We will approach the themes trying to show the place each individual mechanism occupies in the larger picture of the organism's effort to keep the composition of it's fluids constant. We hope the readers will find we could describe the two subjects in a coherent and logical way, so Nephrologists can refresh their memories and Internists can also find the review can benefit their practices.

The articles on water-electrolyte balance and acid-base equilibrium are short, structured versions of the course sessions with same names organized by the Department of Nephrology – Hospital Fernando da Fonseca (two editions in 2011 and 2012 and a third, in preparation for 2015).

It would be pretentious to prepare these articles as textbook chapters. There are several excellent general books on these subjects that will always be better choices for those who want exhaustive reading material.

Our aim is simply to summarize in writing the pedagogical approach of the course: starting with the analysis of the components of the homeostatic systems responsible for maintaining body composition stable as regards water, electrolytes and acid-base determinants, we try to describe and explain the clinical changes observed in practice in terms of the adaptations to varying intakes, organ dysfunctions or even homeostatic system malfunction.

This focusing in homeostatic physiology allows one to deal most times with clinical situations, laboratory tests and therapy in a rational way, as opposed to memorizing and recalling lists of alternative hypothesis.

HOMEOSTAT

In a general purpose definition, an homeostat is a system that keeps something stable even when subjected to external influences that would tend to displace or change that “thing”. A roly-poly is a simple example of a homeostat: whatever you do to it or disturb its position it always returns to the upright position. So, one or more variables can be defined that are kept within narrow limits by a system that monitors the variable and sets in motion actions that oppose the effects of disturbing external disturbances and tries to bring regulated variable back to a steady state.

There is a large body of knowledge about the homeostats that goes beyond the notion of homeostasis (keeping a constant composition "internal milieu"), including plans and mathematical models for general purpose homeostats able to some learning from experience and include behavioural and volitive capacities. The merits go to the pioneering works of Ross Ashby with contributions from Alan Turing in the early days of cybernetics and systems theory. W. Ross Ashby´s famous "Design for a brain" [1] goes from the general homeostat to the "planning" of a rudimentary brain, but already endowed with many human capabilities. The project faced difficulties due to intrinsic complexity of human biology and the extreme limitations of the electronic hardware that then existed, but the theoretical groundwork they laid is the basis for today's computing science.

A biological homeostatic system has sensors in afferent limbs that keep monitoring several biological parameters, a central integrator, and effector limbs that control mechanisms exerting actions that oppose external disturbances, dampening or nullifying its internal repercussions.

A few notions are worth further comment:

– many regulated variables are subjected to more than one regulating system;
– afferent signals from different areas may carry messages of opposing meaning to the centre;
– single regulating systems may influence more than one variable;
– effector mechanisms have multiple actions, either with antagonist or with synergic effects on systemic variables;
– some regulating systems correct the disturbance by bringing the variable to its initial value, while others seem to accept another value, as long as it is stable (a 0 net balance is reached);
– recruitment of mechanisms takes place in some extreme situations;
– response hierarchy is sometimes detected.

In summary, we can see we have a large knowledge on vast aspects of the regulation mechanisms keeping the body composition constant, but the information about the integrative net and its superstructure is not perfect and, at best, very fragmented.

Even facing a complex system whose detailed functioning we do not understand, there are some approaches that seem useful.

Regarding the regulation of the composition of the body in water and main solutes, the approach that consist in considering 2 main homeostatic systems in separate terms allows for a reasonable understanding of reality in health and disease. The two main systems are 1- Regulation of osmolality: anti diuretic hormone (ADH), thirst, variable urine dilution and 2- Regulation of extra-cellular fluid (ECF) volume, sodium balance, effective arterial blood volume (EABV).

Again, as regards acid-base equilibrium, the knowledge of the mechanisms responsible for determining CO_2 concentration permits a good understanding of the reality, while the comprehension of the regulation of the metabolic component is more fragmentary and partial.

Conflict of interest statement: None declared

References

1. Ashby, W. Ross. Design for a Brain-The Origin of the Adaptive Behaviour. 2nd Edition. New York, N.Y.: John Wiley & Sons Ltd, 1960.

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